IMPACT OF ATM TRAFFIC CONTROL ON MPEG-2 VIDEO QUALITY

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ABSTRACT

In this paper, a performance study of controlled MPEG-2 video traffic over an ATM network is presented. ATM networks are able to support variable bit rate (VBR) video sources. However, to implement QoS contract enforcement, traffic policers such as a Leaky Bucket need to be incorporated in order to change the VBR characteristics of a video stream. Our study investigates the video quality achievable by different traffic policing mechanisms. We use cell loss, frame corruption, and mean square error (MSE) to evaluate the influence of different traffic policers on the quality of the transmitted video stream. The performance evaluation is accomplished by simulating an ATM network using real MPEG-2 video streams. In our study, we also consider the layered video coding offered by the MPEG-2 standard. With traffic control, layered video achieves significant quality improvement for video transmission over ATM as compared to the one-layer case.

1. INTRODUCTION

ATM networks are able to support variable bit rate (VBR) video sources. However VBR video is very bursty. To implement QoS contract enforcement, traffic policing is necessary.

There have been numerous works reported that studied VBR video over ATM networks. Typically two methods have been employed: (1) controlling the coding procedure and generate a constant bit rate stream [1] and (2) using traffic polices [2]. The first approach will result in video quality degradation due to insufficient bits allocated for complex frames, while the second approach is able to control video streams without video quality degradation. What distinguishes our work from the prior studies is as follows. First, we expand the study of traffic polices to include: (1) Input Buffer with constant output rate, (2) Leaky Bucket with cell-discard control scheme [2], and (3) Leaky Bucket with cell tagging in conjunction with a partial buffer sharing priority ATM switch [3]. Second, we employ both the number of corrupted frames and MSE as the measures of the received video quality, while in the prior works many researchers use the cell loss statistic of a video stream over ATM networks [2]. We show that the proposed quality measures predict the perceived video quality better than the cell loss statistic. Third, we consider the maximum end-to-end delay requirements of different video applications. Fourth, our study is based on ATM network simulation, driven by real video streams rather than analytical models [4]. Finally, we extend our work to the quality control of two-layer scalable video services.

In the case of two-layer scalable video streams, the base layer is critical for video reconstruction. We consider only signal-to-

noise-ratio (SNR) scalability, since this is the most representative scalability of all MPEG-2 options. We demonstrate significant quality improvement for video transmission over ATM networks using layered coding.

The remainder of the paper is organized as follows. In Section 2 we describe the system under consideration. In Section 3 we examine the influence of different traffic policers on the quality of one-layer video streams. The quality study is extended to two-layer video streams in Section 4.

2. SYSTEM DESCRIPTION

The system under consideration is shown in Figure 1. It includes an ATM switch, a number of video sources, traffic policers, and a destination.

![ATM system diagram](image)

**Figure 1.** ATM system diagram.

The switch model used is exemplified by a 2×2 switch in Figure 2. At the switch's input side, cells destined to a particular switch output port are collected in a corresponding virtual input buffer. During each switch time slot, a certain number of cells (corresponding to the speedup of the switch, which is 12 in our study) are chosen randomly in each virtual input buffer and are transmitted to the corresponding output buffer (with a buffer size of 100 cells each). Cells remaining in an input buffer will be dropped after each switch cycle.

![ATM switch model used](image)

**Figure 2.** ATM switch model used.

The internal switch speed was set to 6 Mb/s (with a speedup of 12) and the switch is connected to 72 Mb/s physical links. This rather low link rate was chosen to obtain a reasonable simulation runtime (less video sources have to be used to generate realistic switch loads). Longer simulation runs with faster switches and...
links and more video sources show that the results presented and conclusions drawn in this paper are also valid for higher switch and link rates (e.g., OC-3).

The study was done using a real MPEG-2 video clip from the trailer of the movie Titanic. It is approximately 45 second long (consisting of 1408 frames) with a mix of short high and low action scenes. The movie was encoded with the following group of picture (GOP) pattern: IBPBBPBBPBB. In this study, we assume that a video stream is packaged into raw 53 byte ATM cells. Higher protocol layer packets (e.g., AAL packets) are not considered here.

Two video applications are considered: interactive video and one-way broadcasting. For interactive video, a maximum end-to-end delay (including encoding, cell packaging, transporting, decoding, and displaying of frames) of 125 ms is assumed [5], while for one-way broadcasting, a maximum end-to-end delay of 500 ms was chosen. Cells received by the destination that would result in a higher end-to-end delay will be dropped.

In this study, we assume that if during a video transmission a received frame is different to the original frame, this frame is corrupted. In most cases, lost cells during a video transmission result in small blank squares within a corrupted frame due to missing macroblocks.

Our ATM simulator is based on the ATM simulator developed by NIST [6] and was adapted to incorporate real video sources and the various traffic policies discussed in this study. All simulation results shown are the average of 60 independent simulation runs.

### 3. EFFECT OF ATM TRAFFIC POLICERS ON ONE-LAYER VIDEO

In this section, we investigate the effects of various traffic policies on the quality of one-layer MPEG-2 video streams. We study three traffic policies: 1) Input Buffer with constant output rate, 2) Leaky Bucket with cell-discard control scheme, and 3) Leaky Bucket with cell tagging in conjunction with a partial buffer sharing ATM switch.

For the Input Buffer policer, the buffer output rate is fixed and is chosen such that the ATM switch operates at 90% capacity for any scenario (e.g., for 12 video streams, the individual buffer output rate is 5.4 Mb/s). The general leaky bucket policer model is depicted in Figure 3 [2]. The Leaky Bucket consists of an input buffer of size $IB$ and a token buffer of size $TB$. Cells drain out of the input and token buffers with a rate of $IBR$ and $TBR$, respectively. $TBR$ was chosen such that the switch operates at 90% capacity for any scenario, while $IBR$ was set to be $IBR=TB/T+TBR$ with $T$ the frame duration of 30 ms [2]. Every cell entering the network places one token into the token buffer. We consider two different leaky bucket policies: a policer with cell discard and a policer with cell tagging. In the policer with cell discard, if the input buffer is full, an incoming cell will be discarded, while when the token buffer is full, an outgoing cell will be discarded. In the policer with cell tagging, non-conforming cells will not be dropped but will be tagged as low priority. The cell tagging policer will be used in conjunction with a partial buffer sharing ATM priority switch proposed in [3]. In this switch, only a portion $\gamma$ of the overall output buffer can be used by low-priority cells (tagged cells) while high-priority cells (non-tagged cells) can use the overall output buffer. The structure of the partial buffer sharing ATM switch is exemplified by a 2x2 switch in Figure 4. In the following, output buffers with a total length of 100 cells and a varying $\gamma$ ($\gamma = 10, 50, \text{ and } 80 \text{ cells}$) are assumed.

![Figure 3. General model of a Leaky Bucket.](image)

![Figure 4. 2x2 priority ATM switch model.](image)

We first investigate how the Input Buffer policer affects the video quality. Figure 5 depicts the cell loss and frame corruption achievable with this policer, with a policer input buffer size of 300 and 600 cells. We examine the video quality for end-to-end delay limits of 125 ms and 500 ms. The VBR case is depicted for comparison (in this case, all cells transmitted have a delay of less than 125 ms). It can be concluded that only for one-way broadcasting (delay limit 500 ms), the use of the input buffer policer results in a higher video quality (lower frame corruption) than in the VBR case. This policer can not be used effectively for interactive video applications (higher frame corruption as compared to the VBR case).

Furthermore, when comparing the cell loss and frame corruption in the 300 cell / 500 ms case, it is obvious that the cell loss statistic, which is used by many researchers to judge video quality, does not realistically reflect the actual video quality degradation (small cell loss but large percentage of corrupted frames). Thus, in this paper, frame corruption rather than cell loss is used to predict the video quality.

Figure 6 depicts the percentage of corrupted frames obtained using the Leaky Bucket policer with cell discarding ($IB = 600 \text{ cells}; TB = 50, 100, \text{ and } 200 \text{ cells}$). Compared to the VBR case and to the Input Buffer policer (Figure 5 b), the Leaky Bucket policer is unable to enhance the quality of the video, even for the one-way broadcasting case (delay limit of 500 ms). A token buffer size of 100 cells results in the lowest percentage of corrupted frames. More cells are dropped in the policer if a smaller token buffer is used, while more cells are dropped in the switch (the burstiness of the traffic increases) when a larger token buffer is used.
In Figure 7, the percentage of corrupted frames achievable using a Leaky Bucket policer with cell tagging in conjunction with a partial buffer sharing ATM switch is depicted. In this scenario, all cells experience an end-to-end delay of less than 125 ms.

Compared to the Leaky Bucket policer with cell discard, the use of the cell tagging policer (together with the priority ATM switch) results in higher video quality (low number of corrupted frames). Also, if the token buffer size and the size of the low-priority buffer in the ATM switch are chosen properly (e.g., $TB = 50$, $y = 80$), more video streams with a high quality can be supported as compared to the VBR case for one-way video broadcasting and interactive video applications.

4. TRAFFIC CONTROL ON SCALABLE VIDEO STREAM

In the case of MPEG-2 video coding, the standard provides several scalable options for multiresolution video transmission. We investigate in this research how the scalability of the video stream can be integrated with the ATM traffic control. In general, a compressed video stream is partitioned into two layers based on some selected criteria. We adopt the most representative scalability, signal-to-noise ratio (SNR) scalability for this research. The base layer of the video stream carries essential information of the video stream while the enhancement layer, after appropriate combination with the base layer, is used to improve the overall quality of the video. For SNR scalability, the base layer and the enhancement layer have the same spatial and temporal resolution. As a result, the combination of these two layers is straightforward.

When the scalable video is transmitted over a priority ATM switch, the base layer cells are labeled with high priority since the base layer carries critical information of the video stream. The enhancement layer cells, on the other hand, are labeled with low priority. We assume that the cell loss in the enhancement layer will have limited impact on the quality of the video at the receiver. Since the impact of the cell loss in the base layer is quite different from the impact of the cell loss in the enhancement layer, we adopt the MSE as the measure of the video quality in the layered transmission of the MPEG-2 video. No obvious degradation can be observed when the cell loss occurs only in the enhancement layer.

Figure 8 shows the average number of lost frames in 60 simulation runs for the single-layer and SNR scalable video transmission without any traffic policers. It is evident that the scalable video transmission significantly improves the frame...
loss performance since the frame loss in the enhancement layer only does not cause frame loss in the reconstructed video. Figure 9 shows the results on MSE of the transmitted video under several different traffic policers. We have examined two traffic policers on SNR scalable video transmission: (1) Input Buffer policer on both base and enhancement layers; and (2) Input Buffer policer on base layer and Leaky Bucket policer with cell discard on enhancement layer.

When the Input Buffer policer is applied to SNR scalable video transmission, we set the buffer rates of the base layer and enhancement layer to be 3/4 and 1/4 of the buffer rate for the single layer video transmission. For the base layer video, we choose the input buffer size to 300 cells. Simulations show that for the input buffer in the enhancement layer policer the buffer size of 5 cells results in the best video quality. A smaller buffer leads to a higher cell loss in the enhancement layer, while a large buffer admits more low-priority cells into the network that may result in a higher loss of base layer cells in the network.

![Figure 8](image1.png)

**Figure 8.** Number of cases of frame loss in 60 runs.

![Figure 9](image2.png)

**Figure 9.** Mean square error, SNR scalable video, y = 15 cells.

The Input Buffer policer results in a lower video quality (higher MSE, see Figure 9) than the Leaky Bucket policer because more enhancement layer cells are dropped in the Input Buffer than in the Leaky Bucket policer. Such high cell loss may cause frame loss in the enhancement layer. When the loss of synchronization between base layer and enhancement layer occurs due to the frame loss in the enhancement layer, the MSE will be significantly increased. In the case of real-time video transmission, it is extremely difficult to recognize the loss before the interactive display of video streams.

We have developed an intelligent approach to resolve this problem by using the Leaky Bucket policer with the priority switch. In this research, we use a Leaky Bucket with an Input Buffer size of 5 cells and a Token Buffer size of 20 cells only in the enhancement layer as we have seen that the performance of the Input Buffer policer in the base layer is adequate. The simulation results for this approach are shown in Figure 9. Comparing with the other two simpler approaches, the scalable video transmission incorporating Leaky Bucket in its enhancement layer shows the best video quality in terms of the MSE. The improvement in video quality is due to the reduction of the frame loss in the enhancement layer.

5. CONCLUSION

We studied the effects on video quality of several traffic policers for video over ATM networks. This research concludes that the Leaky Bucket with partial buffer sharing ATM switch provides the best video transmission quality. When the token buffer and the low priority buffer sizes are chosen properly, this policer can provide good video quality for both interactive and one-way broadcasting video applications.

We have also investigated the traffic control on scalable MPEG-2 video transmission over ATM networks. With priority switch and the labeling of the high priority to base layer cells, we show that the video transmission performance can be improved by such a traffic control scheme. Both one-layer video and scalable video show similar performance improvement. Among the traffic control schemes we have studied, Leaky Bucket with priority switch provides the best video quality when scalable video streams are transmitted.

6. REFERENCE


